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FISH TAINTING IN THE UPPER GREAT LAKES

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1. LITERATURE REVIEW

In perusing literature on fish tainting problems, one finds that considerable attention has been given to algae, actinomycetes, decaying vegetation and industrial and municipal effluents. These have been quoted as sources of pollution responsible for imparting off-flavour to fresh-water fish. Most of the tainting of the flesh of fish has been correlated with the activities of the petroleum industry and the chemical industries, such as pulp and paper mill operations.

Boetius[1] pointed out that the chlorinated phenols derived from chemical industries can impart a phenolic taste to eels and oysters when the concentration of phenols in the water is as low as 0.001 ppm. The fish and oysters can absorb and store these phenols in their tissues, and the phenolic odour can persist in the fish for as long as a month after disappearance of the pollutant from the water. Bandt[2], as part of an extensive study of pollution by phenols, presented a table of several substances which impart tastes to fish and the threshold concentrations of several phenolic substances at which or above which taste and odour of fresh-water fishes are affected. The Aquatic Life Advisory Committee of the Ohio River Valley Water Sanitation Commission[3] quoted 0.1 mg/l of coal-coking wastes, coal-tar wastes, phenols in a polluted river, and a pure compound of chlorophenol as having been responsible for taste and odour in fish flesh. Other materials causing similar problems at concentrations of 1 mg/l or less were listed as xylenols, p-quinone, naphthalene, α-naphthol and quinoline.

EPA's Water Quality Criteria book[4] listed several substances that can cause impairment in fish flavour. Important among them were: phenolic compounds,

coal tar wastes, gas wastes, sewage containing phenols, petroleum refinery wastes, kraft paper mill wastes and rubber manufacturing wastes. The nature and source of the contaminants that cause off-flavour in fish have been determined in many cases and are reported in the literature [5-12]. Some of these studies were done under controlled laboratory conditions to ascertain the extent to which kraft process pulp and paper mill effluent can cause impaired flavour in fish. Schultze[5] conducted a study to determine which tissues in fish had the greatest affinity for phenols. As a result of an experiment in which a carp was kept in water of 10 ppm of phenols for 5 days and the various tissues analyzed for phenols, Schultze concluded that the greatest concentrations of phenol were in the liver and gills.

Nitta[8] studied the oily odours in fish in a Japan Harbour, near the operations of petroleum refineries and determined in laboratory studies that fish can become tainted in concentrations of oil of 0.01 ppm in water and 0.2% (by ether extraction) in bottom muds. The oily taint was obvious after 20 hrs. of exposure. Krishnaswamy and Kupchanko[12] studied similar problems in Alberta.

Although effluents discharged from chemical plants producing pesticides, coal tar processing, kraft pulp mill operations and oil refineries have been identified as sources of fish tainting, not much is known about the extent to which the specific organic compounds present in these waste discharges can impart off-flavour in fish. Thomas[13] characterized effluents that cause fish to have off-flavours so that industries could determine which component in the discharge was responsible for producing the odour. However, he could not delineate the compounds causing the off-flavour.

Numerous workers have published data describing the contribution of whole mill effluents, process streams and toxic materials (either present or presumed to be present) in kraft mill effluents. In this connection, a significant contribution was made by Fetterolf[6], who accurately identified the source and nature of substances causing tainted fish problems in Muskegon Lake in Michigan. He gave a review of the general problem, summarized Michigan's complaints of fish off-flavour, discussed the mechanics of uptake of tainting substances by fish and related the results of two earlier investigations involving the Menominee River and Muskegon Lake. While investigating the fish tainting complaints in the Menominee River by organoleptic testing procedures, the author [6] concluded that the possible sources of contaminants in the lower river were a sulfite pulp and paper mill, a groundwood mill, two primary sewage treatment plants, a chemical manufacturer and a paperboard mill. Although the source of the tainting problem was not definitely isolated in this river, the author [6] demonstrated that a petroleum refinery discharge in the northeast end of Muskegon Lake and a bleached Kraft Pulp and Paper Mill discharge on the southwestern end of the lake were responsible for the fish off-flavour in these areas. Analyses of water samples for phenol in the different areas of the lake showed a concentration of 0.03 mg/l in the northeast bay, 0.012 mg/l in the river below the refinery outfall and 0.5 mg/l in the effluent. Phenols were also found downstream from the petroleum refinery plant and off the bleached Kraft Pulp and Paper Mill on the southwestern end of the lake. Thus phenol appeared to be responsible for tainting the fish.

Fetteroff[6] suggested four methods by which a fish may take up tainting materials: 1) through the gill membrane into the blood; 2) through the gut membrane into the blood; 3) absorption through skin; and 4) absorption to the mucosa. The gill is probably the major organ for uptake; however, uptake through the gut from tainted food was not ruled out.

Boetius' work[1] mentioned earlier described an experimental study on the tainting of fish and oysters from the chlorophenols derived from effluent of a Danish plant making herbicides and insecticides. Analysis of the wastes indicated the presence of p-nitrophenol and either chlorophenols or herbicide intermediates. It was confirmed by laboratory experiments that these compounds were responsible for the tainting. p-Nitrophenol imparted a taint after 10 days in a 10 ppm solution, while chlorophenols imparted a taste to fish flesh at 0.001 ppm. A similar problem was investigated at the same time in regard to tainting of oysters by chlorophenols in Limfjord. Oysters were found to be tainted by chlorophenols at a concentration of 0.0001 ppm within 4 days at 16°C. Boetius felt that the oysters and the eels concentrated the phenols and stored them in their fatty tissue.

Flavour panel studies were conducted by Farmer et al[14] to detect flavour changes in fish resulting from exposure to various pulp mill effluents of Domtar Fine Papers Ltd., Cornwall, and to effluents treated to remove odour and taste. Barometric well, Foul water condensate, Peabody wash water and Seal tank effluents were identified as the problem sources causing flavour tainting in fish exposed to pulp mill effluents. The authors found that the total mill effluent imparted an objectionable flavour to fish when it was used

at the level of 10% of the water entering the tanks in which fish were held. This is 3 times the normal concentration which is likely to occur in the St. Lawrence River at the mill outfall. At the 0.33% level of the total mill effluent, which would be the level if a difuser were installed in the river for the mill effluent, no objectionable flavour was imparted to fish except in long term trials. The problem sources, Barometric well, Foul water condensate, Peabody wash water and Seal tank, when used as the 4 point source equivalent to 6% of the total mill effluent (the proportion of the four effluent sources normally present in the total mill effluent gives a 11.6% level) caused a taint in fish. Removal of the Peabody wash water to provide the 3 point source of effluent used at a level equivalent to 1% total mill effluent gave a significant improvement in flavour. The difference observed between tainting from the 4 point and the 3 point sources suggests that the Peabody wash water which contains 13.4 ppm of phenolics was responsible for the greater tainting in the 4 point source. Removal of the Barometric well effluent from the 3 point source to provide the 2 point source of effluent, used at a level equivalent to 1% of the total mill effluent gave no further improvement. This suggests that the objectionable flavour in the 3 point source came from either the FWC or the Seal tank effluents. Since FWC is almost as high in phenolics (11.6 ppm) as the Peabody wash water, FWC may have contributed significantly to the objectionable flavour. However, FWC was also found to contain a high level of dimethyl disulfide (4.7 ppm) which may have imparted off-flavour to fish This compound is contained in Seal tank effluent as well, at a fairly high level (2.2 ppm) and might be responsible for tainting the fish in this effluent. This conclusion is supported by the fact that the three of the effluent sources

making up the 4 point source (FWC, Peabody wash water and Seal tank) when used individually, rendered the fish unpalatable.

Fish exposed to effluent sources, treated with Activated Sludge plus Aerated Lagoon, plus Turbulent Contact Absorber in series were less objectionable than fish exposed to the untreated 4 point, 3 point and 2 point effluents. The effluent treatments in increasing order of effectiveness were concluded to be Turbulent Contact Absorber, Activated Sludge and Aerated Lagoon.

2. HISTORICAL REVIEW OF PROBLEMS IN COMMERCIAL FISHING IN THE UPPER LAKES

THUNDER BAY

Commercial fishing has seriously declined at Thunder Bay over the past several decades. A fish tainting problem first led to market rejections of local catches by the Federal Fisheries Officer forty years ago. At the present time there is no significant recreational fishing in the Thunder Bay area, particularly in the Lower Kaministikwia River mainly because of the low fish populations resulting from impaired water quality.

In the past, Thunder Bay supported a good commercial fishery for herring, whitefish and several other species. In recent years, it became apparent that fish populations were changing by reduced catches of the more valuable species and larger catches of the coarser varieties such as chub. In addition, inadequate organization of the industry and lack of markets caused a further decline of this industry (Ontario Department of Treasury and Economics, 1970)[15].

NIPIGON BAY

In the past, the major use of Nipigon Bay, other than for waste assimilation, has been the commercial exploitation of several fish species. The bay supports a variety of potentially exploitable fishes. Listed in order of economic importance, these include: walleye, Stizostedion vitreum; whitefish, Coregonus clupeaformis; lake trout, Salvelinus nameycush; cisco, Coregonus sp.; yellow perch, Perca flavescens; and smelt, Osmerus mordax. Of these species,

the walleye has been considered the mainstay of the fishing industry in the bay.

In the last decade, changes in the walleye population of Nipigon Bay have reduced this fishery from one of major proportions to a level where commercial exploitation is no longer considered to be profitable. These changes have included: (1) a deterioration in flesh quality (unnatural flavour) resulting in market rejections and financial losses to the fisherman, (2) a decreasing catch-per-unit-of-effort related to a decline in abundance, (3) the disappearance of walleye from their spawning bed in the Nipigon River (Ryder, 1968)[16]. While other commercial species are still present, marketing problems owing to the unnatural taste and the general impracticality of fishing these species without the insurance of the "blue chip" walleye, has placed the entire fishery of Nipigon Bay in a dangerous position.

The problems experienced by commercial fishermen in Nipigon Bay were summarized and translated to the OWRC in a letter from a spokesman for the Association of Commercial Fishermen of Thunder Bay District. Quotes from the aforementioned letter are as follows:

> "Where the Yellow Pickerel have gone elsewhere to spawn and inhabit, the Whitefish are not so choosey. The Whitefish are still in and around the polluted area but there is no sense catching them as they are not saleable."

and

> "Direct losses were incurred by Mr. Gordon Dampier in 1961 of $2,500 when his Whitefish were rejected and dumped. Mr.

> Harold Dampier experienced $500 in losses in like manner. These men were told by the Baltimore Fish Company not to ship any more to them as they would not accept them at all in the future. Other fishermen in this same family along with the two mentioned commenced shipping to Kemp Fisheries of Port Arthur and were similarly told the same thing, however, with a proviso that the shipper guarantee his fish be of an edible quality. Kemp Fisheries in their advice to these men related that their customers in Detroit and Duluth refused to buy anymore Canadian Fish as their customers became nauseated with these fish".

In this letter, the Association of Commercial Fishermen of Thunder Bay District has maintained that wastes from Domtar Newsprint Limited are responsible for direct money losses to members of the association. In addition, the recent changes in the fishery of Nipigon Bay have raised conjecture concerning a possible relationship between kraft mill wastes which are discharged to Nipigon Bay and the decline in the walleye population.

Limited information indicates that the walleye of Nipigon Bay gained access to their spawning grounds in the Nipigon River by ascending the western channel of Nipigon Bay. It has been postulated that chemical wastes from the Domtar Newsprint Limited might have formed a chemical barrier along the western portion of Nipigon Bay, thereby thwarting accessibility and negating reproduction of walleye on their natural spawning grounds.

SPANISH RIVER AND ADJACENT NORTH CHANNEL

Since 1947, complaints have been made by commercial fishermen and others, of the odour of the water and foul taste of fish from the Spanish River downstream from Espanola. The odour was alleged to have been that peculiar to the K.V.P. (Kalamazoo Vegetable Parchment Co., Ltd.,) plant which began operations at Espanola in 1946 (presently known as Eddy Forest Products Limited). The plant produced kraft and groundwood pulps which were used in the manufacture of paper products. During the 1960's, an average of 16,000,000 Imp. GPD of waste materials were discharged to the Spanish River.

The Research Council of Ontario undertook a study of chemical, physical and biological conditions in the river in 1950. The results of this study (Dymond and De Laporte; 1952)[17] confirmed the existence of odour in the water and foreign flavour in the major game fish in the river, the yellow pickerel (*Stizostedion vitreum vitreum*).

In 1958, personnel of the OWRC investigated a complaint from a commercial fisherman, that fish caught in the river near its mouth had been rejected by buyers in Sudbury, Montreal and New York on the basis of an objectionable flavour described as "carbolic" (Voege, 1958)[18]. Analyses for phenols showed the presence of 6 and 7 ppb in water at the fishing site but none in pickerel from the same location. The fish, however, yielded 1 to 25 ppm tannins, indicating that other wastes of an odorous nature could have been absorbed also.

In a letter to the Commission regarding this investigation, Mr. W.J. Sullivan,

K.V.P. Company, stated that most of the taste and odour problem would stem from two waste streams: the turpentine decanter underflow and the hot water accumulator overflow. Subsequently, attempts were made to eliminate the turpentine decanter underflow from the final effluent. This was accomplished by 1960. The hot water accumulator overflow was re-directed by the spring of 1965.

The tainting of fish prevented their acceptance at market, however, as late as 1964 (Millest and Neil, 1961[19]; Neil, 1964[20]). At that time an expansion of mill capacity was proposed. It was decided, therefore, to determine the incidence of foreign flavour in fish from the Spanish River before mill expansion took place. The results of panel tests to evaluate the flavour of fish collected from the Spanish River in the summer of 1965 are presented in the next section.

3. STUDIES OF FISH TAINTING IN THE UPPER LAKES

THUNDER BAY

During biological surveys carried out in October 1965 and August 1966 by OWRC staff, it was found that fish taken from the Kaministikwia River were severely tainted. Sources of pollution in the lower Kaministikwia River at the time of these surveys included: a) untreated sewage from one-half of the 50,000 inhabitants of Fort William; b) the Great Lakes Paper Company with discharges of kraft-process waste; and c) wastes from the Abitibi Power and Paper Company Limited (Mission Mill).

During the August 1970 water quality survey by MOE, the average concentration of phenolic substances, which contribute to taste and odour problems in water and which are believed to contribute to tainting of fish flesh, ranged from 9 to 14 ug/l in the Kaministikwia River downstream from the Great Lakes Paper Company Limited outfall, as well as at the mouth of the three channels. The monitoring data indicated average phenolic concentrations of 7-8 ug/l upstream from the Great Lakes Paper Company Limited, while the downstream levels averaged 24 ug/l. The highest concentrations of phenolic substances were encountered in the north part of the Inner Harbour, which is influenced by the waste inputs from the Abitibi Provincial Paper, a Division of Abitibi Forest Products Limited. The average levels in the area of the harbour extending north from the mouth of the Current River ranged from 19 ug/l to 28 ug/l (Station 134, 135, and 518 in Figure 1). Southwards from the mouth of the Current River to approximately half-way between McVicar Creek and the Current River, phenolic concentrations ranged from 5.8 to 12.4 ug/l (Stations

132, 519 and 138). Elsewhere in the Inner Harbour average levels ranged from 1 to 3.4 ug/l. The concentrations of phenolic substances in the Thunder Bay Outer Harbour were highest in the vicinities of the paper mill outfalls, the Lillian Street sewer and near the mouths of the Kaministikwia River channels. In general, the levels decreased with increasing distance from the sources. For example, near the mill of the Abitibi Paper Company Limited, Fort William Division, the level ranged from an average of about 9 ug/1 near the breakwall to an average of 5 ug/1 at a distance of ½ mile from the breakwall. At about ½ mile from the mouths of the channels, the average levels ranged from 3.2 to 8.4 ug/1. The levels decreased with increasing distance into the bay but still remained at approximately 1.5 ug/1 at a distance of 3 miles from shore.

In a letter dated June 9, 1969 from Mr. D. Silvertson of Silvertson Bros. Fisheries, Duluth, Minnesota to Mr. H. Swinson of the Minnesota Division of Fish and Game the fact was noted that whitefish from Grand Portage Bay have been tainted with a foul oil-like flavour for several years. The incidence of tainting was suggested to be one fish in twenty. In a further letter dated June 26, 1969 from D. P. Caplice of the Ontario Water Resources Commission to Dr. C. H. D. Clarke of the Ontario Department of Lands and Forests, Mr. Caplice noted that for several years there have been complaints of tainted whitefish from Thunder Bay. Following the above complaints a program of flavour evaluation of whitefish from the Thunder Bay area was undertaken by the Ontario Ministry of the Environment in 1970. It was found in this study that severe flavour impairment occurred due to the exposure of the fish to kraft mill effluent. The whitefish used in these flavour evaluations came from five separate areas

with the control fish obtained from Lake Nipigon. The experimental fish were from Green Point, four miles northeast of the mouth of the Kaministikwia River; Perry Point, 15 miles northeast of the mouth of the Kaministikwia River; Sturgeon Island, 10 miles southwest of the mouth of the Kaministikwia River and Grand Portage Bay, 30 miles southwest of the mouth of the Kaministikwia River. On the basis of the taste panel test, the presence or absence of foreign flavours as compared with the control was recorded as follows: O absent; +-barely perceptible; ++-definite; +++-strong. Table 1 indicates that there was a significantly higher incidence of foreign flavour in the fish of Grand Portage Bay compared to the control fish of Lake Nipigon. Three of the 38 fish tested from Grand Portage Bay would be considered as strongly tainted. This evaluation is reasonably consistent with Mr. Silvertson's observations of 1 fish in 20 being strongly tainted. This difference in flavour between the control fish of Lake Nipigon and the fish from Grand Portage Bay is attributed to the presence of actinomycete fungi growing in the organic bottom of Pigeon Bay adjacent to Grand Portage Bay. Tainting was also indicated in the fish from Green Point. The fish of Sturgeon Point showed a slight deterioration in flavour. Samples of fish from Perry Point did not reflect a tainting problem. The nature of the taint in fish from Green Point was inconclusive. The gasoline-like or kerosene-like taints obtained, were however, suggestive of industrial contamination, such as where kerosene is used as a foam control agent in the pulp and paper industry. The source of the tainting in Green Point might be the pulping complex at Thunder Bay. A map showing the areas of sampling is included as Figure 2.

NIPIGON BAY

Following complaints from commercial fishermen that whitefish (Coregonus clupeaformis) taken from the upper portion of Nipigon Bay were tainted by discharges from Domtar Newsprint Limited (Red Rock Mill), whitefish were collected from five different areas of Nipigon Bay for taste panel evaluation. Forty-eight fish collected from September 23, 1967 through to November 2, 1967, were subjected to critical taste test evaluations. As MacInnes Point is fairly remote from the Red Rock mill and fish from this area had never been rejected because of unusual flavours, this location was chosen as a control site.

Figure 3 shows the fish sampling stations in the Biological Survey of Nipigon Bay conducted in 1967. Table 2 presents the data on the incidence and intensity of foreign flavour in total number of fish samples tasted from each location. Table 2 also gives the incidence of foreign flavour on a percentage basis. It can be seen that in the control group 33% of the samples possessed a foreign flavour and 15% of the control group possessed a definite to strong flavour. These percentage figures were similar to the flavour ratings of the fish from the Outan Island, the Clay Banks and Caribou Point.

Of the 111 fish samples tasted from the vicinity of the Red Rock mill, 92% were rated as having a foreign flavour and 71% were considered to possess a definite to strong flavour.

On the basis of evaluation by the taste panel technique the following conclusions were drawn:

- Compared to the control fish from MacInnes Point there was a significantly higher incidence of foreign flavour at the Red Rock mill's sampling site. There were

also significant differences in the incidence of foreign flavour between the Red Rock mill site and the Outan Island, Clay Banks and Caribou Point sites.

- Seventy-one percent of the samples from the Red Rock Mill had a definite to strong foreign flavour. This incidence of foreign flavour was significantly higher than the incidences found at the four other sites in Nipigon Bay.
- The incidences of foreign flavour recorded for the fish from Outan Island, Caribou Point and the Clay Banks were not significantly different from the control.
- Eighty percent of the fish from the Red Rock Mill area were considered to be tainted, while none of the fish from the Clay Banks, Outan Island, Caribou Point or MacInnes Point were deemed to be so.

NORTH CHANNEL

Phenolic substances in the kraft mill wastes are believed to contribute to the objectionable taste of the fish taken from the Spanish River and the adjacent North Channel. Samples collected during the November 1967 biological study indicated phenolic concentration of 10 ug/l immediately downstream from the Eddy Forest Products Limited mill at Espanola (formerly Kalamazoo Vegetable Parchment Co. Ltd.). The levels were still at 3 ug/l near the river's mouth. The levels of phenols from stations B to M (Figure 4) are higher than the recommended limit (not detectable) of the Ontario Ministry of the Environment.

Station	P	A	B	E	G	N	L	M
Phenols (ppb)	2	0	10	8	6	4	3	3

The character of the river water below Espanola was reflected in the taste of yellow pickerel taken from the Spanish River in the summer of 1965. The percentage incidence of foreign flavour in pickerel from Onaping Lake, Spanish River at Massey and the North Channel is given in Table 3. The notations are the same as in the Thunder Bay Study. The data are based on the total number of samples presented from each location and include the percentage of samples falling into each intensity category.

Reference to Table 3 shows that of the 17 control samples presented 41.2 per cent were rated positive for foreign flavour, 11.8 per cent definite or strong. Due to the subjective nature of taste panel tests, a certain percentage of control samples can be expected to be rated as positive. The incidence of total positive found here was somewhat higher than usually encountered, due perhaps to the small number of samples available.

Of the 51 samples of pickerel from Massey, 84.3 per cent were classified as having a foreign flavour; 52.9 per cent as definite or strong. The data for the samples from North Channel were similar to these: 84.6 per cent positive and 48.7 per cent definite or strong.

The intensity of foreign flavour in fish from Massey and North Channel was similar. Of the samples from Massey, 31.4 per cent were classed as barely perceptible, 31.4 per cent as definite and 21.6 per cent as strong. For the samples from North Channel these data were, respectively; 35.9, 30.8 and 17.9 per cent.

Using the incidences of foreign flavour in control samples as those expected, the data for samples from the other locations were subjected to Chi Square tests.

The results of these tests are indicated by asterisks (*) in Table 3. The incidence of samples positive for foreign flavour and of those rated definite or strong were significantly higher in samples from both Massey and the North Channel than in those from Onaping Lake.

In all categories of foreign flavour intensity except "barely perceptible", the data for Massey and North Channel samples were significantly different from those expected on the basis of the controls. (In order to apply the Chi Square test to the "strong" classification which yielded a datum of 0 for controls, it was necessary to assume an incidence of one positive sample, i.e., 6 per cent, in the controls).

The foregoing discussion deals with foreign flavour in all fish samples from each location. To obtain an estimate of the number of individual pickerel which could be considered tainted, an arbitrary criterion of two-thirds of the samples from each fish rated definite or strong by the panel was adopted. On this basis none of the three fish from Onaping Lake was tainted. Four of the eight pickerel from Massey and four of the seven from the North Channel, however, were tainted.

When presented with the pike and bass specimens from Massey, five of the six panelists classified both as acceptable, even though a few felt they had a barely perceptible foreign flavour.

As part of the Research Council's study of the Spanish River in 1950, pickerel from the river and another group from Lake Mindemoya were sent to the Fisheries Research Board at Halifax for taste panel evaluation. The report on these tests

(Dymond and De Laporte, 1952) stated that on a scale of 0 (unacceptable) to 100 (perfect score), the fish from Lake Mindemoya averaged 64 per cent, those from the Spanish River, only 39 per cent. The latter had "an objectionable bad taste, somewhat like decaying mud". The 1965 study indicated that the objectionable foreign flavour still persisted in a large percentage of pickerel from the lower river and adjacent North Channel.

Information obtained from the Industrial Wastes Division, OWRC, after the study of 1965, indicated that possible sources of odour-and taste-producing materials originating with the K.V.P. Company, Espanola, included: any turpentine decanter underflow and hot water accumulator overflow allowed to reach sewers; losses from the brownstock washing area due to spillages and foaming; screen room effluents containing black liquor and possibly anti-foaming agents carried over in the pulp from brownstock washing operations; bleach plant effluents containing extracted organics; and any spills or losses occurring in the pulp mill, bleach plant and chemical recovery process.

The Eddy Forest Products mill (formerly K.V.P. Company) has now installed primary treatment facilities and is investigating condensate stripping and biological treatment of its discharges to the Spanish River.

THE OUTLOOK

The previous discussions clearly indicate that a significant factor in the delays experienced in finding a solution to the problem of fish tainting was the difficulty in correctly identifying the sources of the taint and their proper treatment. Also, it should be stated that the Ministry's policy on pollution abatement for the pulp and paper industry in the Province has been that priority be given to the control of suspended solids and oxygen demanding waste inputs and acute toxicity.

Recently, in a publication[21] of this Ministry (1973) relating to the status of industrial water pollution in Ontario, taste and odour producing materials from kraft pulping operations have been discussed. Referring to the research work performed by "Domtar" at the Cornwall mill, the report suggests that condensate waste streams from the digester (foul water condensate) and evaporator areas (Barometric well) together with recovery furnace flue gas condensate (Peabody washwater) are the principal contributors to odour and fish-flesh tainting. In Ontario, no further work has been done on the problems of taste and odour since the Domtar study.

A considerable amount of work has been done by industry on the treatment of total and selected kraft mill wastes, by a variety of biological treatment processes and preliminary indications are that efficient biological treatment will probably elliminate taste and odour producing materials. Several kraft mills are studying the feasibility of condensate stripping for their operations. When these strippers are operational, an evaluation is contemplated to determine any additional treatment facilities that might be required. In each case, the Ministry is encouraging the mills to install condensate stripping as soon as possible.

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Table 1

Incidence of foreign flavour in whitefish samples from Western Lake Superior

Collection Area	No. of Samples	Rating of Fish Flavour				Total Positive	Total-Def. to Strong
		0	+	++	+++		
Lake Nipigon	48	29	9	6	4	19	10
(control)%	100	60.5	18.7	12.5	8.3	39.6	20.8
Green	78	20	30	17	11	58	28
Point %	100	25.6	38.5	21.8	14.1	74.4*	35.9*
Perry Point to Knoble	42	24	10	6	2	18	8
Point %	100	57.1	23.8	14.3	4.8	43.0	19.0
Sturgeon	84	34	29	10	11	50	21
Island %	100	40.4	34.6	11.9	13.1	59.5*	25.0
Grand Portage	108	25	30	28	25	83	53
Bay %	100	23.1	27.8	25.9	23.1	76.8*	49.0*

* Chi-Square values significantly different from controls at 95% level of confidence.

Table 2

Incidence and Intensity of Foreign Flavour in Fish Samples from Nipigon Bay

Collection Site	No. of Samples	Foreign Flavour				Total Positive	Def. Strong
		0	+	++	+++		
MacInnes Point	39	26	7	5	1	13	6
(control)	100%	67%	18%	13%	2%	33%	15%
Red Rock	111	10	22	30	49	101**	78**
Mill	100%	9%	22%	27%	45%	92%	71%
Outan	39	27	10	1	1	12	2
Island	100%	69%	26%	2%	2%	31%	4%
Clay Banks	39	27	7	1	4	12	5
	100%	69%	18%	2%	10%	31%	13%
Caribou	39	30	7	2	0	9	2
Point	100%	77%	18%	4%	0%	23%	4%

* 0 - No Foreign Flavour Present
+ - Foreign Flavour - Barely Perceptable
++ - Foreign Flavour - Definite
+++ - Foreign Flavour - Strong
** - Significantly Different from Control at 1% Level

Table 3

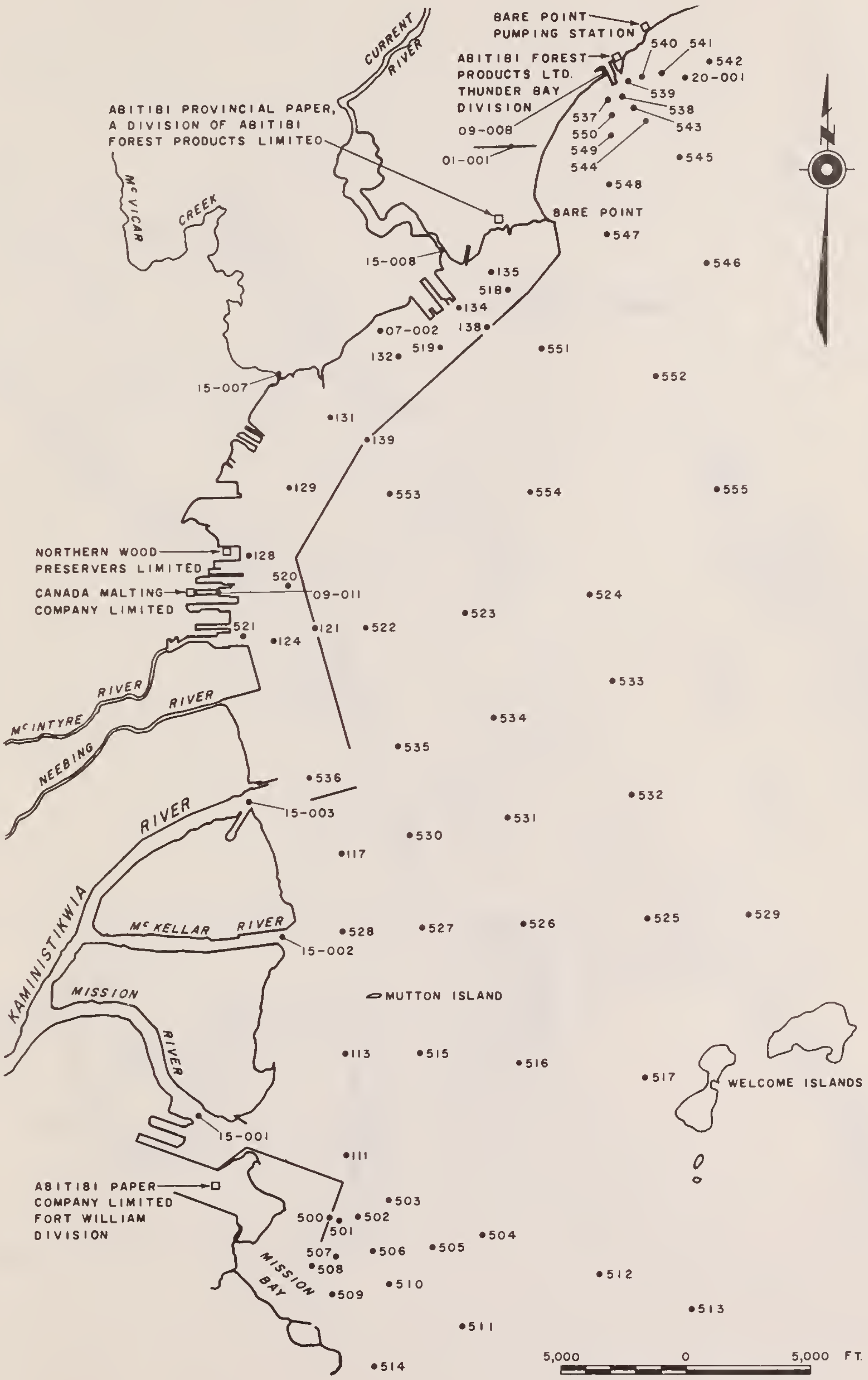
Incidence of Foreign Flavour in Pickerel Samples from North Channel

Collection	No. of		Foreign Flavour			TOTAL	Def. or
Site	Samples	0	+	++	+++	Positive	Strong
Onaping	17	10	5	2	0	7	2
Lake	100%	58.8	29.4	11.8	0.0	41.2	11.8
Massey	51	8	16	16	11	43	27
	100%	15.7**	31.4	31.4**	21.6(**)	84.3**	52.9**
North	39	6	14	12	7	33	19
Channel	100%	15.4**	35.9	30.8**	17.9(**)	84.6**	48.7

* Significantly different from control at 5% level

** Significantly different from control at 1% level

(**) Based on assumed incidence of one control sample +++



DRG Nº 5182

FIG. I SAMPLING LOCATIONS— THUNDER BAY

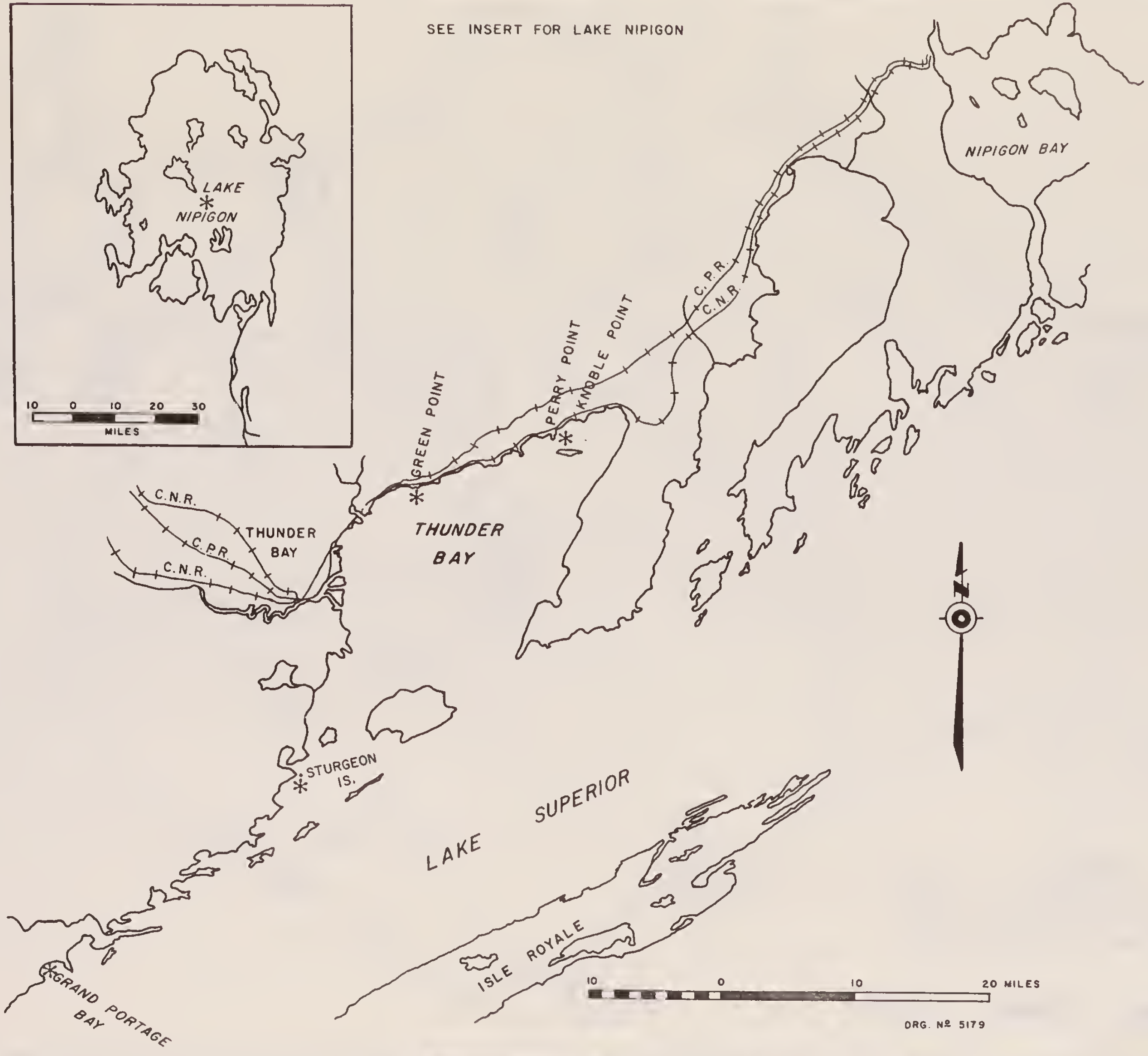


FIG. 2 SAMPLING AREAS OF THUNDER BAY AND GRAND PORTAGE BAY (*)

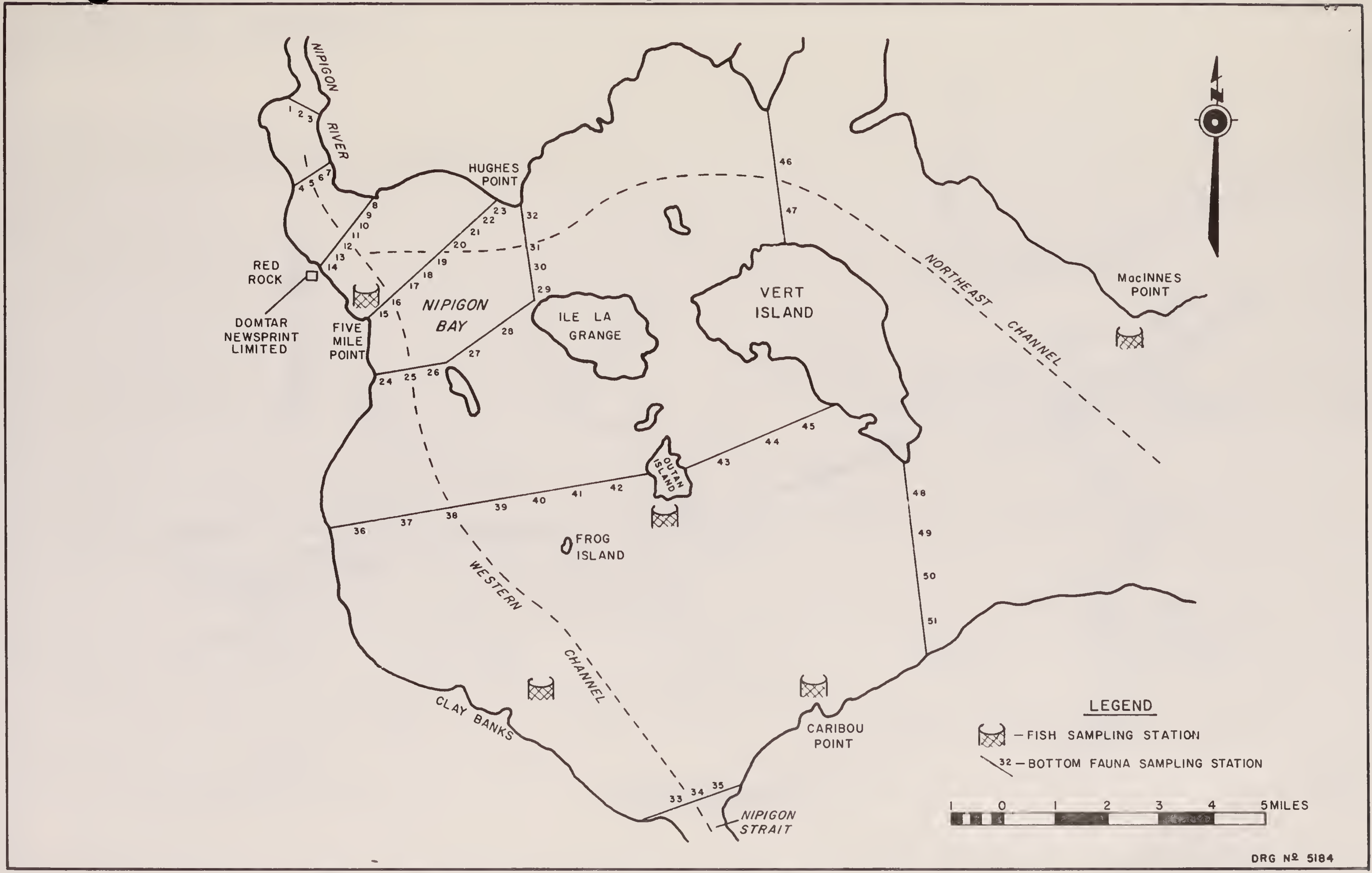


FIG. 3 NIPIGON BAY

LEVELS OF PHENOL

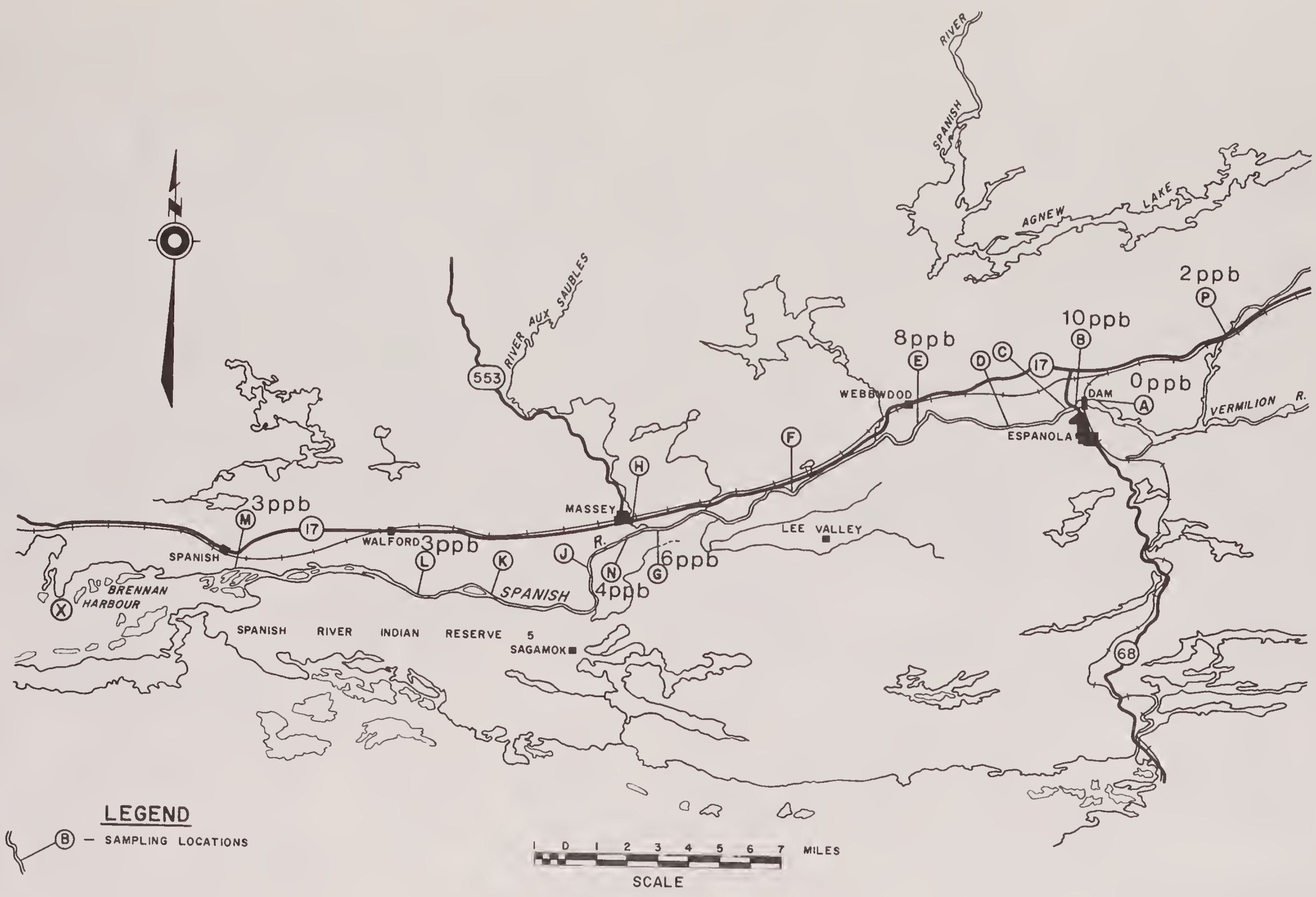


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FIG. 4 SAMPLING LOCATIONS ON LOWER SPANISH RIVER DRAINAGE BASIN

ACCO USA
LINCOLNSHIRE, ILLINOIS 60069
#25971
0 50505 25971 7
BLACK/NOIR/NEGRO
MADE IN USA